

## LONG-TERM EFFECTS OF COVER SOIL DEPTH ON PLANT COMMUNITY DEVELOPMENT FOR RECLAIMED MINED LANDS IN NEW MEXICO<sup>1</sup>

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**Abstract:** Double wedge research plots are used to simultaneously evaluate the effects of cover soil depth and suitable spoil depth on reclamation. A double wedge was constructed and seeded in the fall of 1993 at a coal mine in northwestern New Mexico. The purpose was to determine “optimal” depths of cover soil and suitable spoil. Depth of cover soil ranged from 0 to 90 cm and depth of suitable spoil ranged from 0 to 120 cm. Sample points were established at 49 permanent locations evenly spaced throughout the plot. Vegetation sampling events were conducted in November 2003 and June of 2004 to determine vegetative cover, production, shrub density, and species diversity. Cover soil and suitable spoil depths were used to evaluate the response of cover, production, and diversity. Total cover and production increased with cover soil depth. Rabbitbrush density decreased with cover soil depth, whereas winterfat density increased with cover soil depth. The greatest species diversity occurred at cover soil depth between 25 and 65 cm. None of the vegetation parameters were affected by suitable spoil depth

**Additional Key Words:** Vegetative establishment, revegetation, soil cover depth, vegetative cover, production, shrub density, species diversity, and wedge studies.

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## **Introduction**

Mine land reclamation is dependant upon successful establishment of self sustaining vegetation communities, which is largely dictated by the post mining land use. Successful establishment of these communities is often influenced by cover soil depth, and in some cases by chemical and physical properties of underlying spoil. Numerous studies have been conducted to determine the “optimal” cover soil thickness on mine land reclamation. A few studies have been conducted on the effects of spoil depth on reclamation.

A study conducted by McGinnies and Nicholas (1983) found a positive relationship between cover soil depth and root and herbage production of intermediate wheatgrass (*Agropyron intermedium*). However, cover soil depth beyond 40 cm provided no additional benefit to root biomass production. Doll et al. (1984) examined the interaction between cover soil depths of 0, 20, and 60 cm and suitable spoil depths of 0 to 175 cm for native grasses and crested wheatgrass (*Agropyron cristatum*). This study concluded that the greatest yield of native grasses occurred with 20 cm of cover soil and 50 to 68 cm of suitable spoil. Deeper cover soil (60 cm) resulted in lower yield.

Redente and Hargis (1985) evaluated the effects of soil depth on growth of seeded range vegetation. Seeded grass biomass increased with increasing soil cover up to 60 cm. Conversely, seeded forb and shrub biomass was greatest at 15 cm and decreased with increasing soil cover depths. The biomass of seeded species at 60 cm of cover soil did not vary significantly from biomass of seeded species at 15 cm of cover soil. This was attributed to greater biomass of grasses at 60 cm balancing greater biomass of forbs at 15 cm. The study suggested that if the revegetation objective was to maximize production of a few perennial grasses, then 60 cm of cover soil should be recommended, and if the revegetation objective was to maximize the performance of a greater number of seeded species, then replacement of 15 cm of cover soil should be recommended. Similarly, Crofts et al. (1987) found that 10 to 20 cm of replaced cover soil over spoil resulted in the greatest cover, production, species diversity, and species richness.

Studies of this nature were lacking for the region of northwestern New Mexico; therefore a double wedge was constructed to determine the optimal depth of cover soil and suitable spoil for mine land reclamation in the area. The study evaluated long term vegetative parameter (cover, production, shrub density, and diversity) responses with various cover soil depths to define an optimal cover soil depth for mine reclamation in northern New Mexico.

## **Methods and Materials**

A double wedge plot was constructed at an active coal mine in northern San Juan County, New Mexico to evaluate the depth of both cover soil and suitable spoil with regard to mine reclamation. The double wedge research plot was situated at an elevation of 6,200 feet (1,890 meters) with an annual average precipitation of 30.5 cm. The double wedge is a 1 –ha<sup>2</sup> research plot constructed with suitable spoil and cover soil wedges. The suitable spoil wedge overlies mine spoil and is oriented east to west from a depth of 0 cm (east), and progresses to a depth of 120 cm (west) (Figure 1). The cover soil wedge slopes north to south, from a depth of 0 cm (north), progressing to a depth of 60 cm (south), (Figure 1). The two wedges were constructed so the final plot surface was nearly level. The two wedges were orientated at 90° to one another to provide the simultaneous evaluation of numerous suitable spoil and cover soil depth combinations.

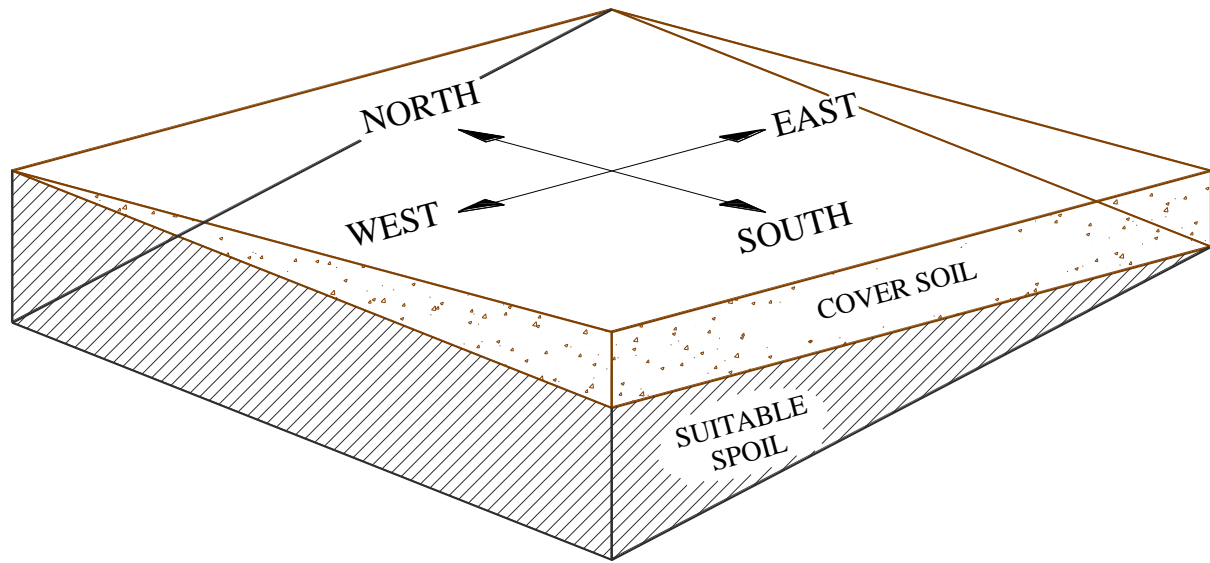


Figure 1 Double Wedge Construction Detail

The construction phase was completed in early 1993, and was seeded uniformly during the fall season with a native seed mixture (Table 1). That same year, 49 evenly spaced sampling locations were established throughout the research plot to determine precise depth of cover soil and suitable spoil. The depths of cover soil and suitable spoil were measured and recorded at each location. The 49 grid locations were permanently marked for future vegetation sampling and monitoring.

Vegetative sampling was conducted in 1994, 1995, 1996, 2003, and 2004. This paper reports 2003 shrub density data and 2004 cover and production data. Shrub density was measured by counting all shrubs within a 6 m radius circular plot and dividing by the plot area (113 m<sup>2</sup>). Calculated shrub density was adjusted to uniform shrubs per m<sup>2</sup>. A complete 6 m radius plot was not possible at sampling locations along the plot perimeter; therefore half circle plots were sampled. Vegetation cover was recorded at 10 cm intervals along two 6 m transects each centered over the grid sampling location. One transect was oriented north-south and the other was oriented east-west. Production was calculated by clipping perennial species within a 1 m<sup>2</sup> plot randomly centered on one of the 6 m transects. These data were used to identify relationships between vegetative parameters and cover soil and suitable spoil depths. The objective was to determine an optimal cover soil depth for reclamation at this mine site and others with similar environmental conditions.

Table 1. Double Wedge Seed Mixture.

Scientific Name	Common Name	Lbs PLS/ac.
<i>Sporobolus airoides</i>	Alkali sacaton	0.6
<i>Sporobolus cryptandrus</i>	Sand dropseed	0.2
<i>Bouteloua gracilis</i>	Blue grama	0.4
<i>Bouteloua curtipendula</i>	Sideoats grama	0.3
<i>Pleuraphis jamesii</i>	Galleta grass	0.4
<i>Achnatherum hymenoides</i>	Indian ricegrass	1.2
<i>Pascopyrum smithii</i>	Western wheatgrass	1.6
<i>Linum lewesii</i>	Blue flax	0.3
<i>Penstemon strictus</i>	Rocky Mountain penstemon	0.2
<i>Ratibida columnifera</i>	Prairie coneflower	0.1
<i>Atriplex canescens</i>	Fourwing saltbush	4.0
<i>Atriplex confertifolia</i>	Shadscale	4.0
<i>Krascheninnikovia lanata</i>	Winterfat	4.0
<i>Purshia tridentata</i>	Antelope bitterbrush	12.1
<i>Rhus trilobata</i>	Oakbrush sumac	4.0
Total		33.3

## Results and Discussions

### Soil Analysis

The cover soils were predominately A and B horizon material from nearby fine loamy Haplustalfs that had been stockpiled about 10 years. The textures were sandy clay loams with a mean clay content of 25.5% (range 21.8 to 29.1%), a mean pH of 7.9 (range 7.6 to 8.2 s.u.), a mean electrical conductivity (EC) of 2.27 dS m<sup>-1</sup> (range 0.57 to 5.01 dS m<sup>-1</sup>), and sodium adsorption ratio (SAR) values ranging from 2.1 to 9.0. The suitable spoil was directly transported from an active mining area and was predominantly a brown sandstone material. The mean clay content was 22.9% (range 11.8 to 27.3%), a mean pH of 7.6 (range 6.1 to 8.6 s.u.), a mean EC of 4.64 dS m<sup>-1</sup> (range 0.79 to 7.9 dSm<sup>-1</sup>) and SAR values ranging from 1.47 to 12.5. Both the cover soil and suitable spoil met the suitability guidelines for topdressing and spoil used by the mine.

### Cover Depths

Cover soil depths measured in 1993 (Figure 2) were used for the 2003 and 2004 comparisons. The average cover soil depth within the research plot was 30 cm (Standard Deviation (SD) 7.6).

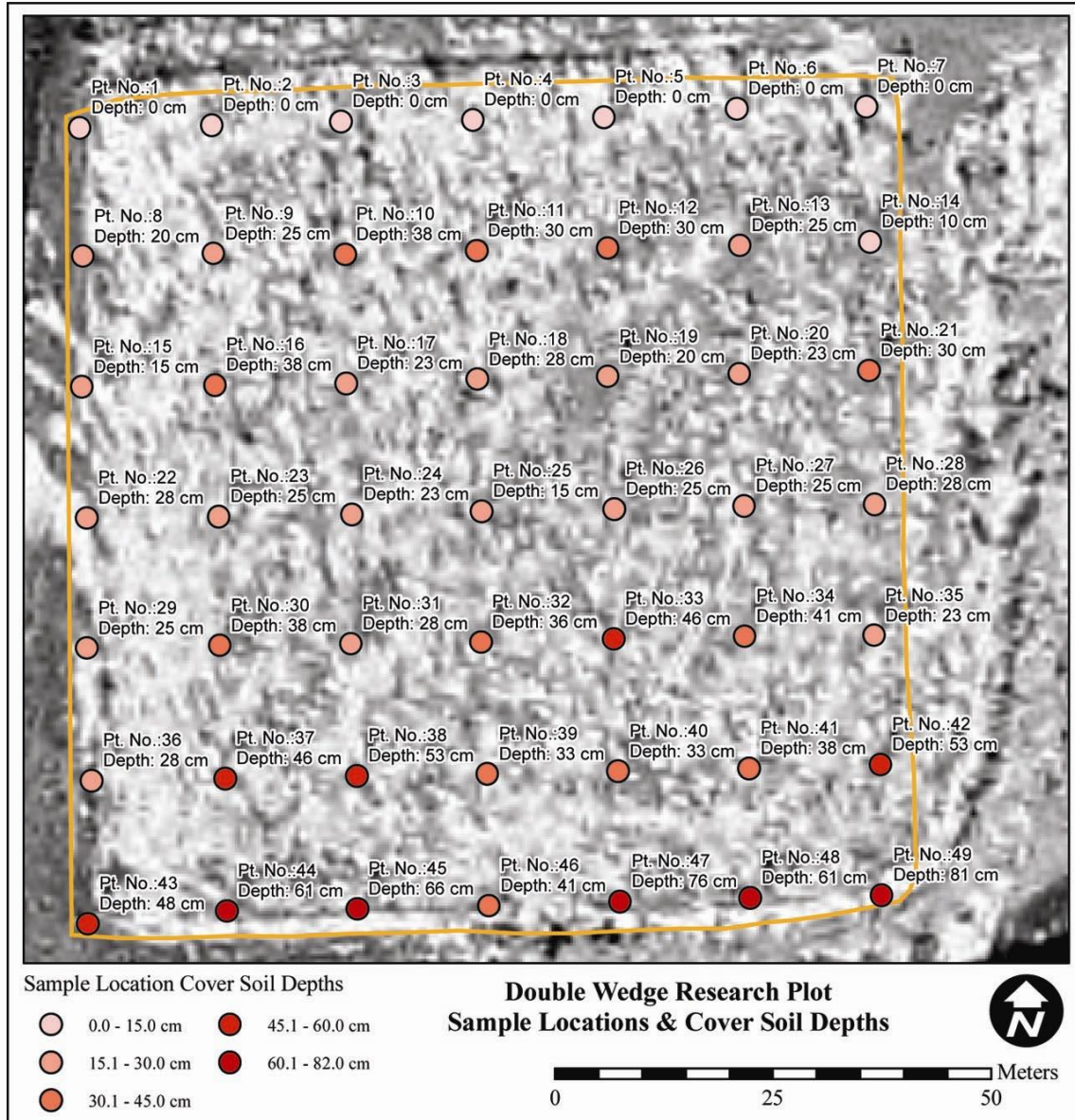


Figure 2 Sample Locations and Measured Cover Soil Depths

### Vegetative Cover

In 2004, the double wedge had an average total vegetative cover of 32.2% (SD 9.7) and perennial vegetative cover of 31.1% (SD 9.8). Total and perennial vegetative cover was compared to cover soil depth at the 49 sampling locations. The scatter diagram and regression analysis indicated there was a positive significant ( $P=0.05$ ) relationship between cover soil depth and both total vegetative cover (Figure 3) and perennial cover (Figure 4). There were no statistically significant relationships between vegetative cover and suitable spoil depth. The mine spoil, under the suitable spoil, also had no measurable influence on either total or perennial vegetative cover. The mine spoil was predominately shale with clay contents of 35 to 40%; pH,

EC, and SAR were similar to suitable spoil and most all samples met the suitability guidelines for spoil.

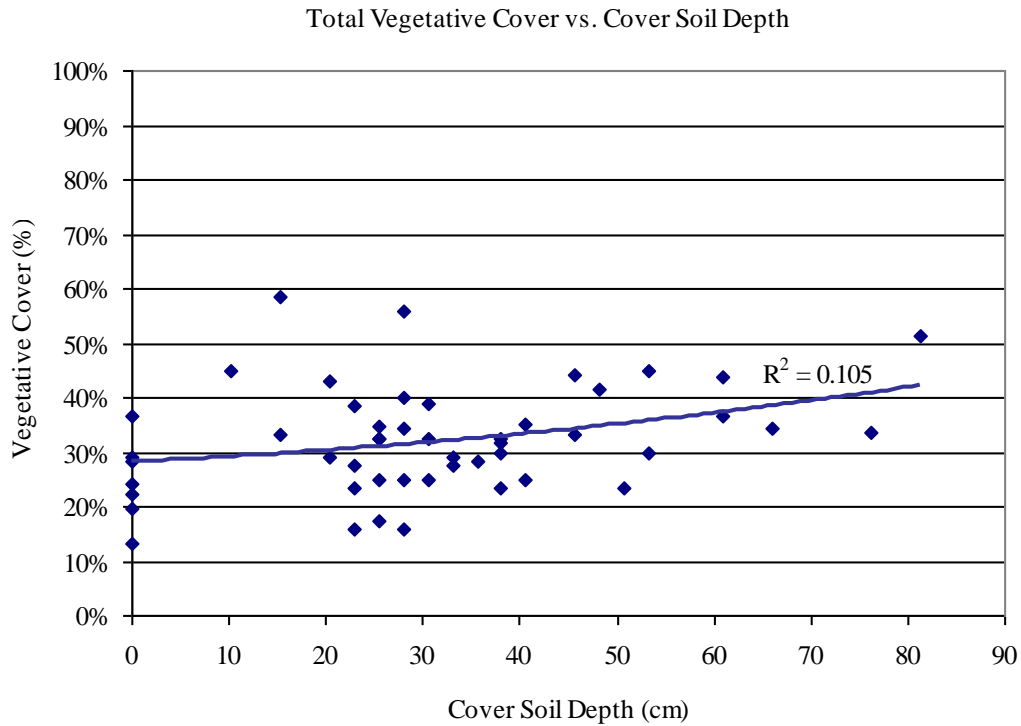


Figure 3 Total Vegetative Cover vs. Cover Soil Depth

Perennial cover for grass and shrub life forms was also plotted against cover soil depth (Figure 5). For clarity, the relationship between forb cover and cover soil depth was not displayed on the graph as it was not statistically significant at the 5% level. Regressions of both grass and shrub cover with cover soil depth were significant at the 1% level. Grass cover had a correlation coefficient of 0.426 and shrub cover had a correlation coefficient of -0.365.

The polynomial regression shows grass cover increasing as cover soil depth increases to 64 cm and then leveling. Total shrub cover decreased with increasing soil cover depth. Areas without cover soil are predicted to support about 65% cover of shrub species and 28% cover of grass species. The shrub cover seems to dominate up to approximately 33 cm of cover soil and thereafter grass cover appears to dominate.

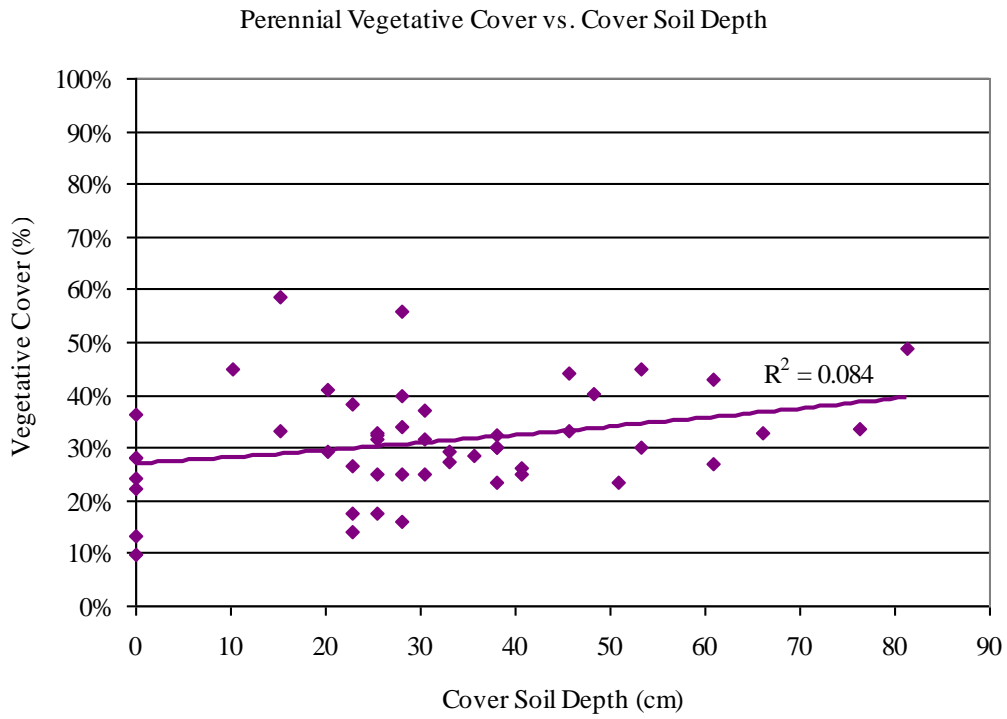


Figure 4 Perennial Vegetative Cover vs. Cover Soil Depth

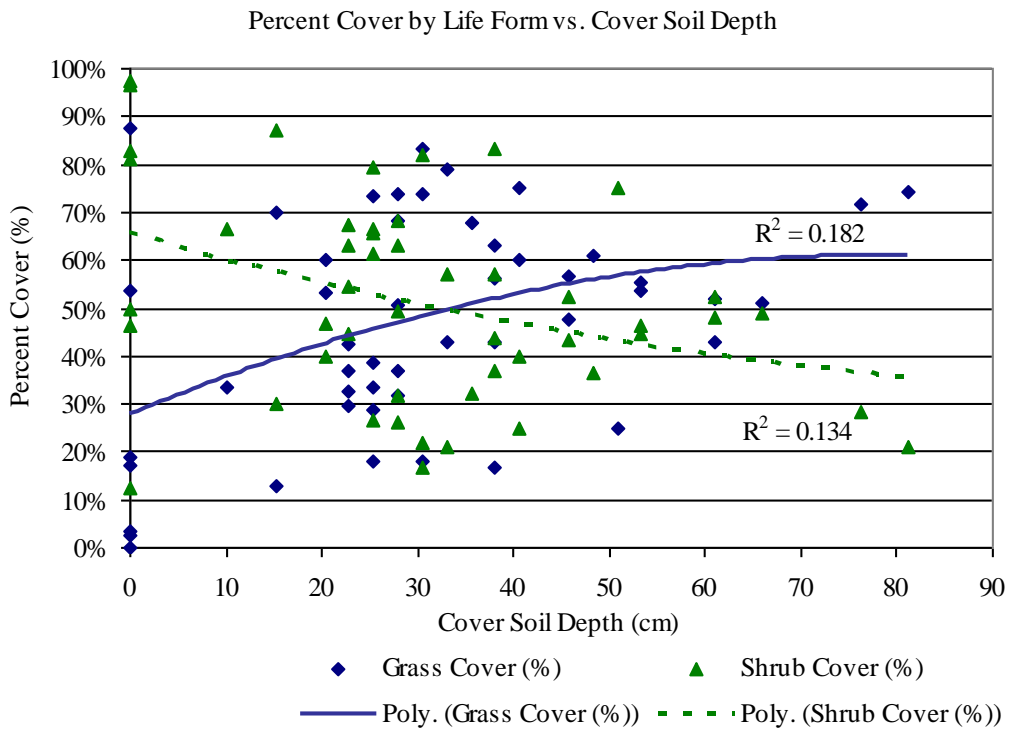


Figure 5 Percent Cover by Life Form vs. Cover Soil Depth

## Production

In 2004, the double wedge had an average perennial production of 813 kg ha<sup>-1</sup> (SD 746). Grasses accounted for 54% and shrubs 46% of the total production. Perennial forbs were rare in the production plots, and therefore were not collected for production sampling. Total production was correlated to cover soil depth (Figure 6). Regression analysis showed a continual increase with depth, correlation coefficient of 0.375 (P=0.01). The regression predicts a total production of 520 kg ha<sup>-1</sup> on sites with no cover soil. There were no statistically significant relationships between production (grass or shrub) and depth of suitable spoil.

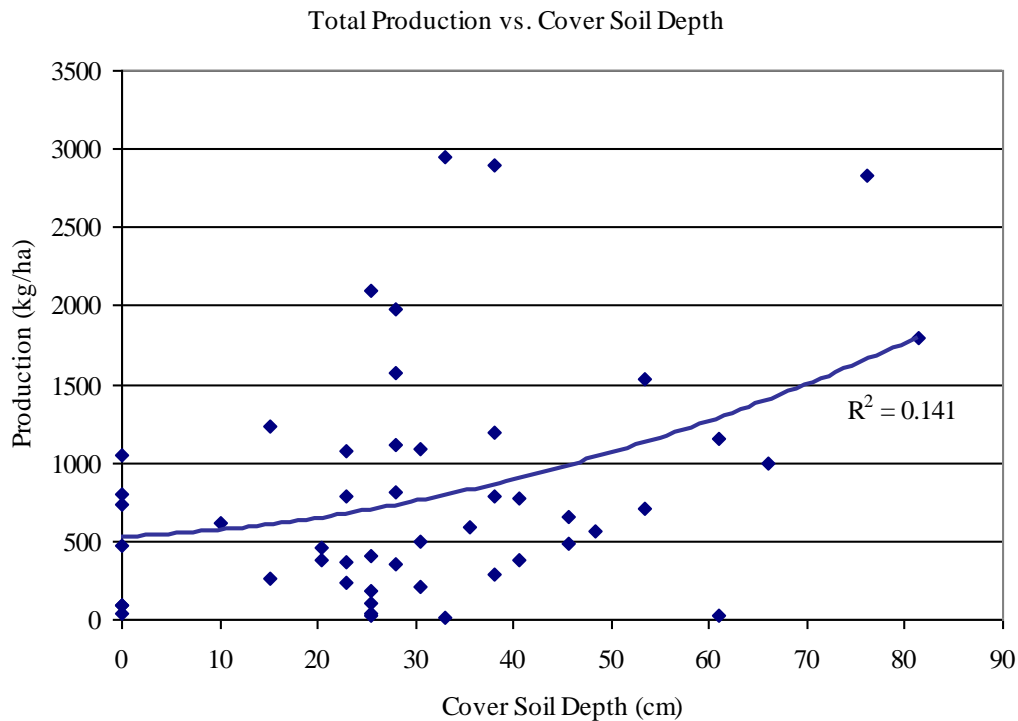


Figure 6. Total Production vs. Cover Soil Depth

Total production by life form was compared to cover soil depth (Figure 7). The regression of grass production, correlation coefficient of 0.402 (P=0.01), indicates a trend of stable production up to 25 cm of cover soil and then a curvilinear increase with cover soil depth to 75 cm. The regression of shrub production, correlation coefficient of 0.083 (P=0.66), indicates no affect of cover soil depth on production from 0 to 75 cm.

## Shrub Density

Shrub density was determined from the 2003 vegetation data. Mean shrub density in 2003 was 3,029 shrubs ha<sup>-1</sup> with a standard deviation of 1,451. Total shrub density was compared to cover soil depths (Figure 8). Regression analysis, correlation coefficient of 0.148 (P=0.72), suggests there is no relationship between total shrub density and cover soil depth. Similar to cover and production, there was no relationship between shrub density and suitable spoil depth.



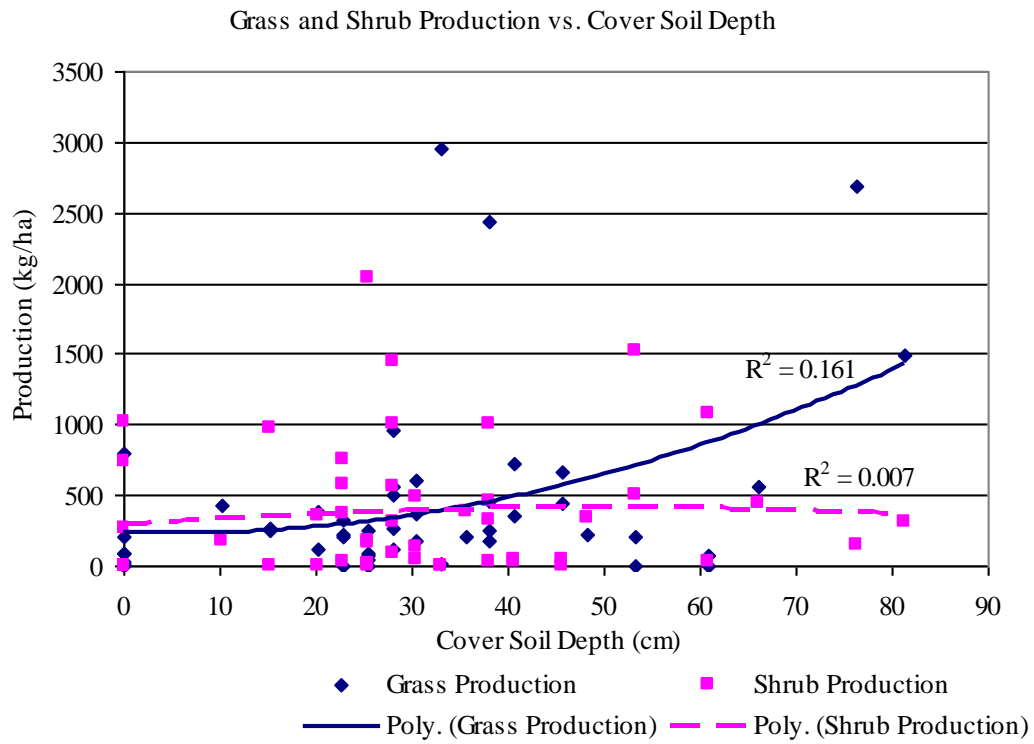


Figure 7 Grass and Shrub Production vs. Cover Soil Depth

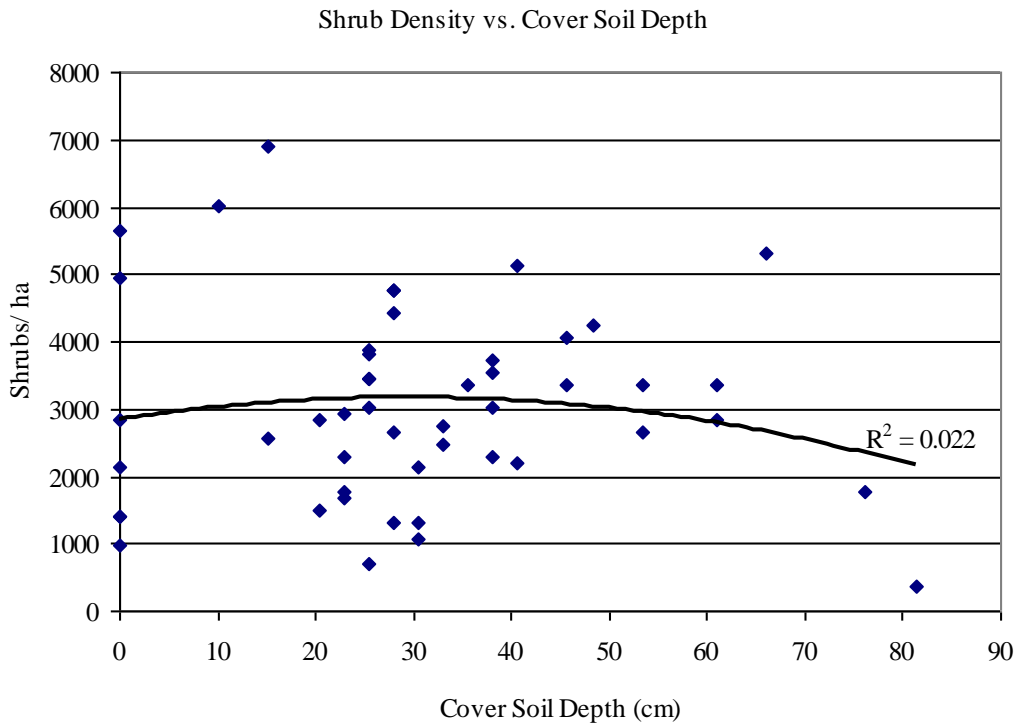


Figure 8 Shrub Density vs. Cover Soil Depth

Scatter diagrams and regression analysis were completed for the three dominating shrub species (Figure 9). The three species evaluated were *Krascheninnikovia lanata* (winterfat), *Ericameria nauseosa* ssp. *nauseosa* (rubber rabbitbrush), and *Atriplex canescens* (fourwing saltbush).

Density of two shrubs, winterfat and rubber rabbitbrush were statistically ( $P=0.01$ ) affected by cover soil depth (Figure 9). Fourwing saltbush density was not statistically affected. Correlation coefficients for the three species (winterfat, rubber rabbitbrush, and fourwing saltbush) were respectively 0.564, -0.548, and 0.151.

Winterfat density appears to increase with cover soil depths of 50 cm and then the density is unaffected or may decline. Conversely, rubber rabbitbrush density continually decreases with increasing cover soil depth (Figure 9). Fourwing saltbush had no relationship to cover depth.

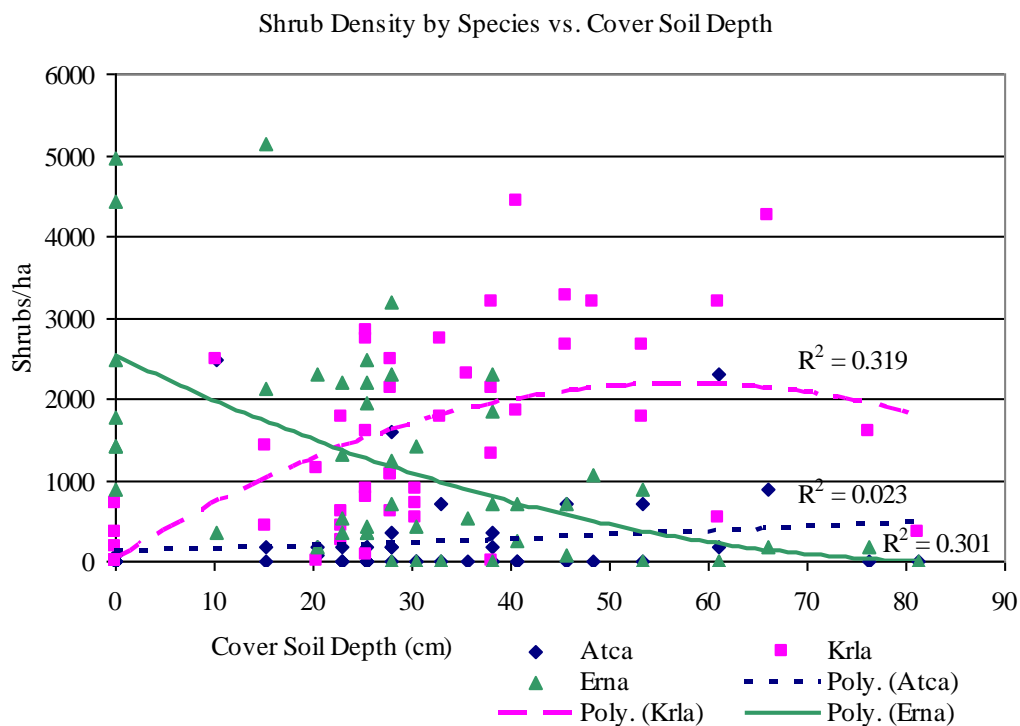


Figure 9 Shrub Density by Species vs. Cover Soil Depth

#### Number of Species per Sample Location

The research plot had a mean of 4.8 species (SD 1.4) occurring at each sample location. The maximum number of species identified at any sample location was seven species and the least was two species.

The number of species per sample location was compared to cover soil depth (Figure 10). Regression analysis, correlation coefficient of 0.358 ( $P=0.05$ ), suggests the highest number of species occurs within cover soil depths of 25 to 65 cm. Cover soil depths shallower than 25 cm and deeper than 65 cm had fewer species than intermediate depths. Again, suitable soil depth was not correlated to the number of species.

Due to the timing of the 2004 sampling, the occurrence of perennial forb species was rare. However, in previous sampling events (1994, 1995, and 1996) several perennial forbs demonstrated a preference to cover soil depths in the range of 20 to 30 cm.

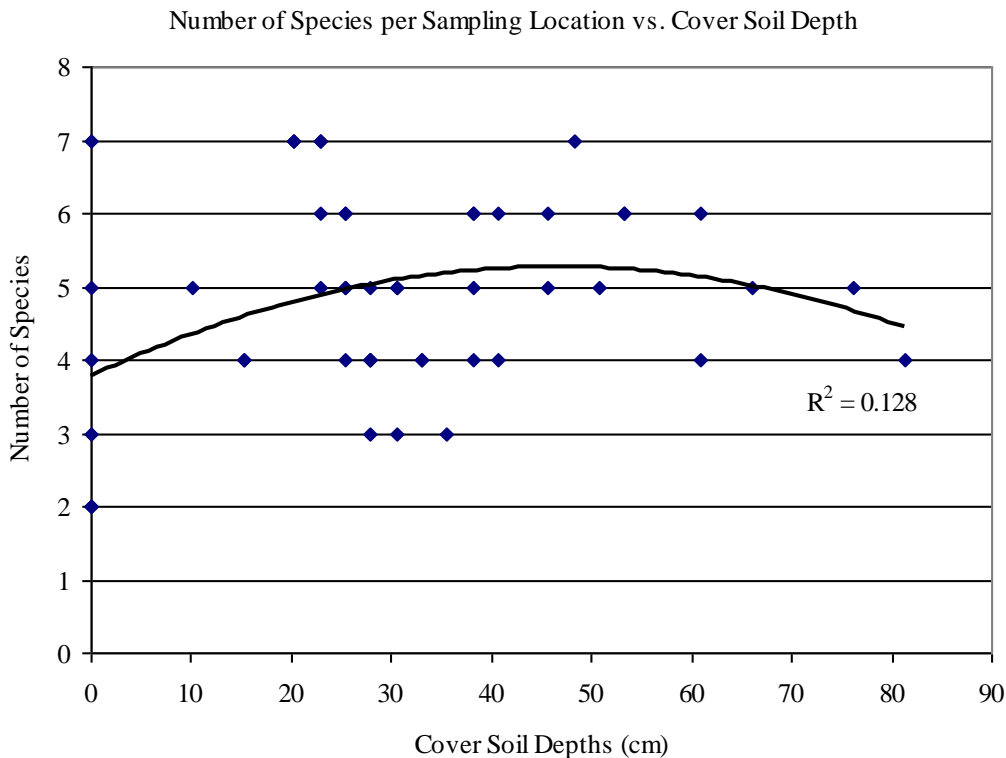


Figure 10 Number of Species per Sampling Location vs. Cover Soil Depth

### Summary

#### Vegetative Cover

Total vegetative cover and perennial cover both demonstrated an increasing trend with cover soil depth. Shrub cover was highest in shallow soils and was inversely related to cover soil depth. Conversely, perennial grass cover was positively related to cover soil depth.

#### Production

Total production increased with cover soil. Total shrub production was relatively unaffected throughout all cover soil depths. Grass production was at its minimum in the shallow soils (25 cm). Grass production was positively related to cover soil depth beyond 25 cm.

#### Shrub Density

The maximum shrub density occurred at approximately 30 cm of cover soil with a density of nearly 3,029 shrubs per ha. Winterfat and rubber rabbitbrush both exhibited significant relationships with cover soil depth. Rubber rabbitbrush had its highest density with no cover soil, and exhibited a decline in density with depth. Conversely, winterfat had its lowest density in the shallow soils, and increased in density to depths of approximately 50 cm. Fourwing saltbush density was not affected by cover soil depth.

### Number of Species per Sampling Location

The mean number of species per sample location was 4.8. It is predicted that at least 5 species will occur at soil depths of 25 to 65 cm. These numbers are projected to be even greater during sampling periods when perennial forbs are abundant. Soil depths of less than 25 cm and greater than 65 cm are projected to have fewer than 5 species.

### Conclusion

The optimal depth of cover for reclamation depends upon the target vegetation community. The varying trends presented by the different vegetation parameters and cover soil depths indicated that certain species and communities have a preference to different cover depths. Shallow cover soils will result in a dominance of shrub species; conversely, deeper cover soils will result in a dominance of grass species. Consequently, varying cover depth throughout the reclaim area will create a diverse and dynamic vegetation community.

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